sPHENIX TPC Option dE/dx Study

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A First dE/dx Study

This is a look at the dE/dx distribution coming straight out of GEANT4.

I am running off of the TPC branch of g4detectors. This is not included in the nightly build, so I am running off of my own build.

I am running Alan Dion's macro Fun4All_G4_tpc_plus_vtx_single.C located in CVS at sphenix/simulation/g4simulation/macros/TPC (but not yet in git).

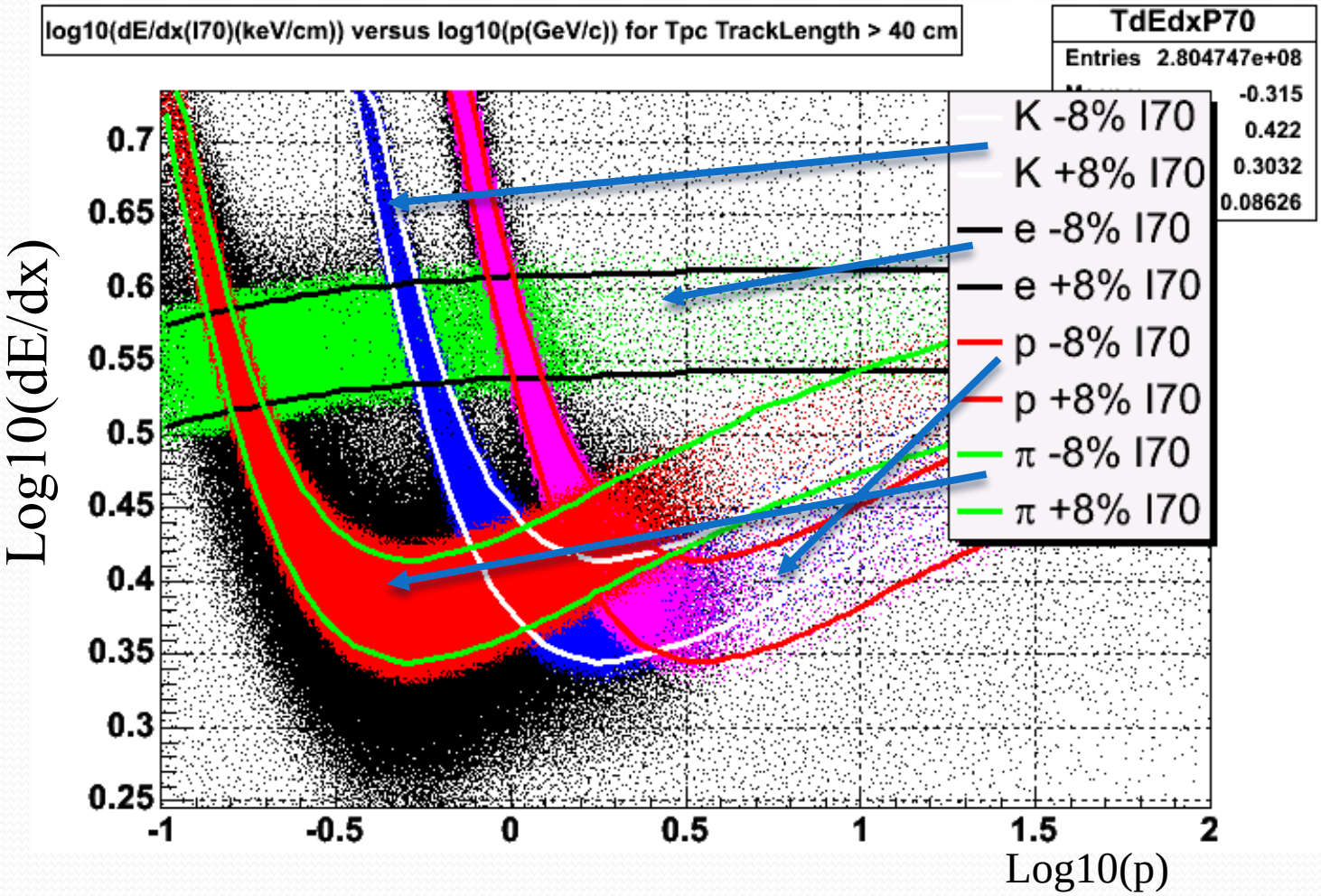
I am looking at single particle tracks traversing the 60 layers of the TPC.

The TPC gas is Argon.

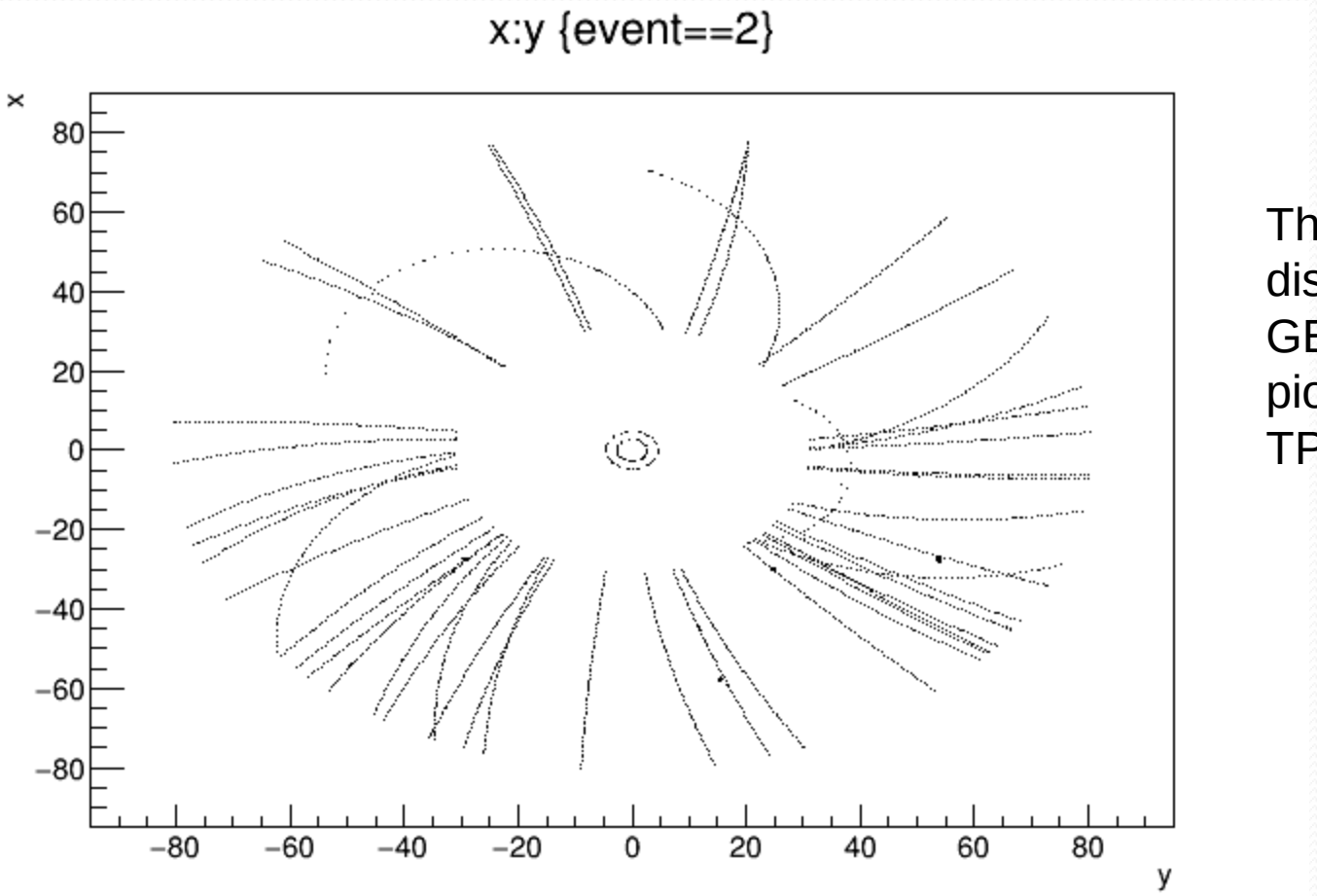
The goal is to try and reproduce the STAR TPC pid plot on the next page.

Using the edep output in the ntp_g4hit ntuple.

Particle ID with dE/dx (STAR data)



GEANT tracks in the TPC



The hit coordinate distribution of GEANT hits from 50 pions traversing the TPC.

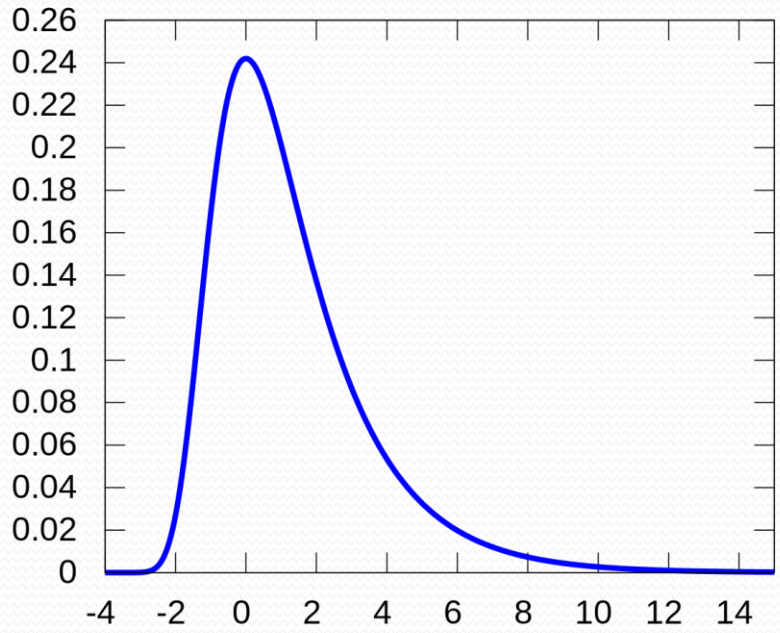
Calculating the truncated mean

The average energy loss per distance traveled for particles traversing matter is described by the Bethe-Bloch formula (from Wikipedia):

For a particle with speed *v*, charge *z* (in multiples of the electron charge), and energy *E*, traveling a distance *x* into a target of elec potential *I*, the relativistic version of the formula reads, in SI units (Sigmund 2006):

$$-\frac{dE}{dx} = \frac{4\pi}{m_e c^2} \cdot \frac{nz^2}{\beta^2} \cdot \left(\frac{e^2}{4\pi\varepsilon_0}\right)^2 \cdot \left[\ln\left(\frac{2m_e c^2\beta^2}{I \cdot (1-\beta^2)}\right) - \beta^2\right]$$

where *c* is the speed of light and ε_0 the vacuum permittivity, $\beta = \frac{v}{c}$, *e* and m_e the electron charge and rest mass respectively.



The resulting dE/dx is a Landau distribution.

The Landau distribution is basically a Gaussian with a long tail.

The Landau distribution can be reduced to the Gaussian by throwing out the highest dE/dx values when sampling across many segments, such as a TPC.

For this study, I will throw out the top 40% of the hits in a track. This is a typical fraction used for TPC PID.

Example from the ALICE TPC

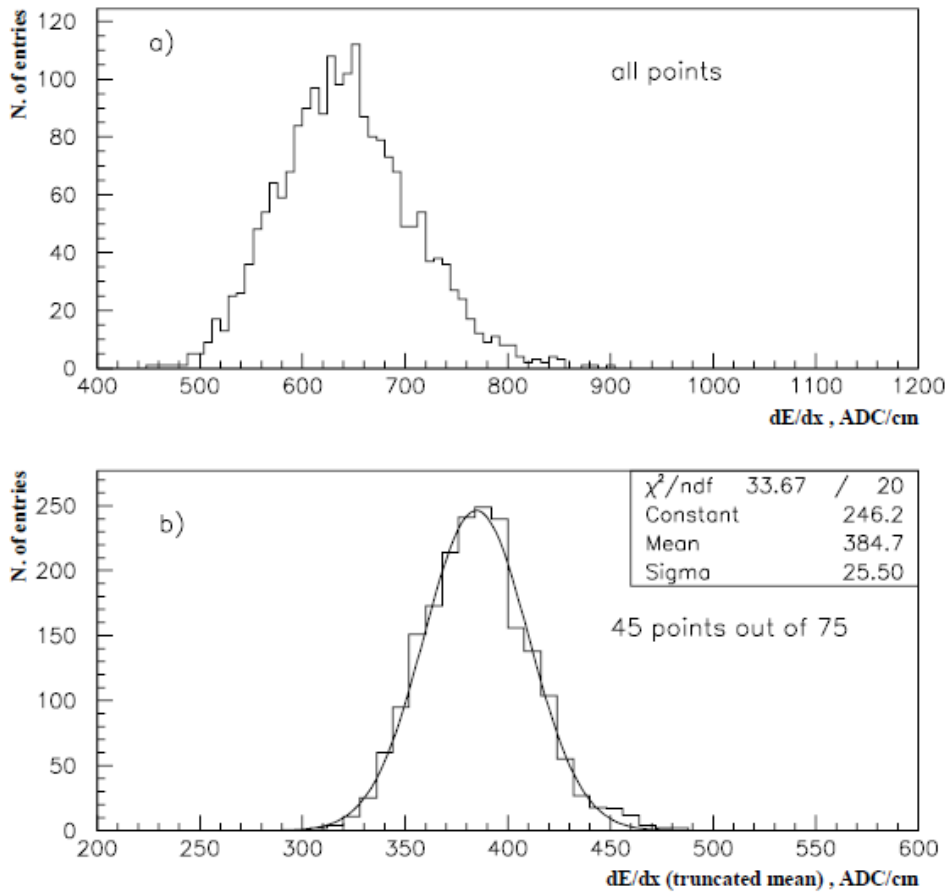
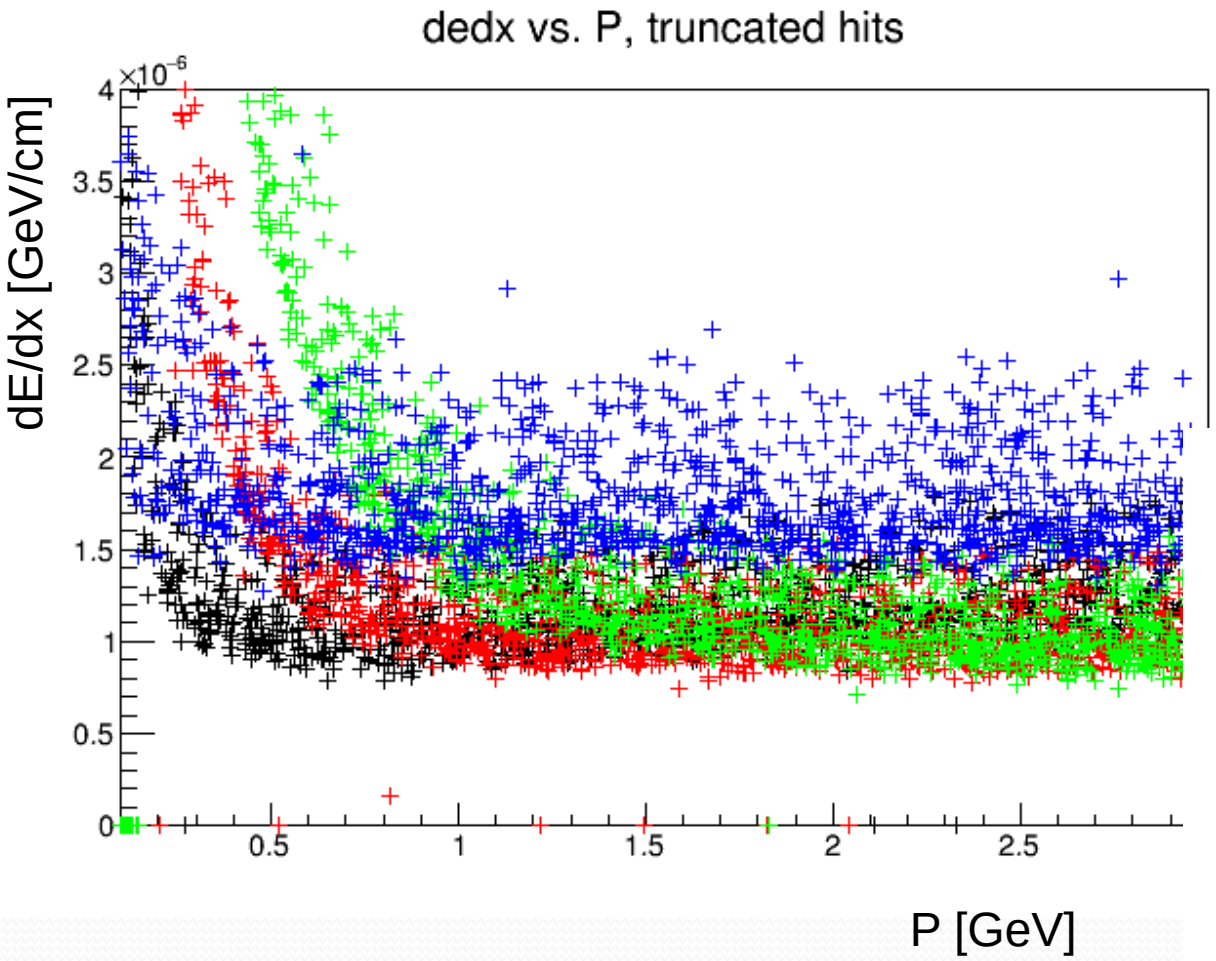


Figure 1: dE/dx distribution for 2 GeV/c pions, obtained by taking into account all measured points per track (a), and as a truncated mean of the 45 lower points, together with a fitted Gaussian, (b).

Procedure

- I have run groups of 1500 particles with a flat p_T spread from 50 MeV to 3 GeV.
- I have run pions, kaons, protons, and electrons.
- The analysis is based only on primary GEANT tracks → perfect tracking, no merging of hits, etc.
- For each primary GEANT track, a list of the GEANT4 edep values for each associated GEANT hit is made.
- The top 40% of the edep values are rejected. The remainder is averaged and entered in the plots that follow. There is one entry per GEANT track.

Truncated Mean dE/dx vs Momentum



Black = pions

Red = kaons

Green = protons

Blue = electrons

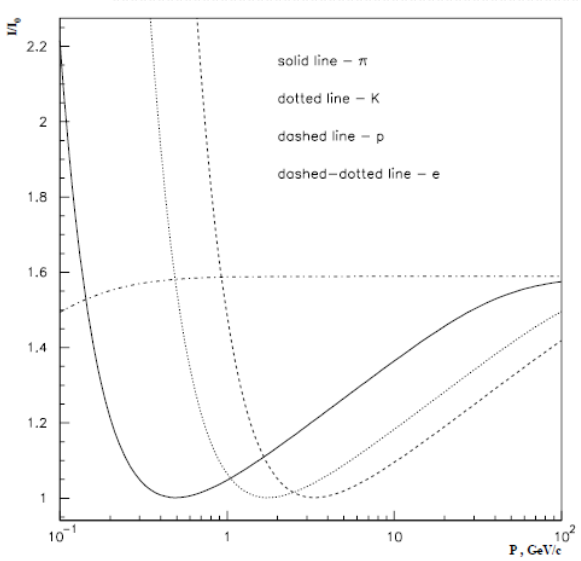
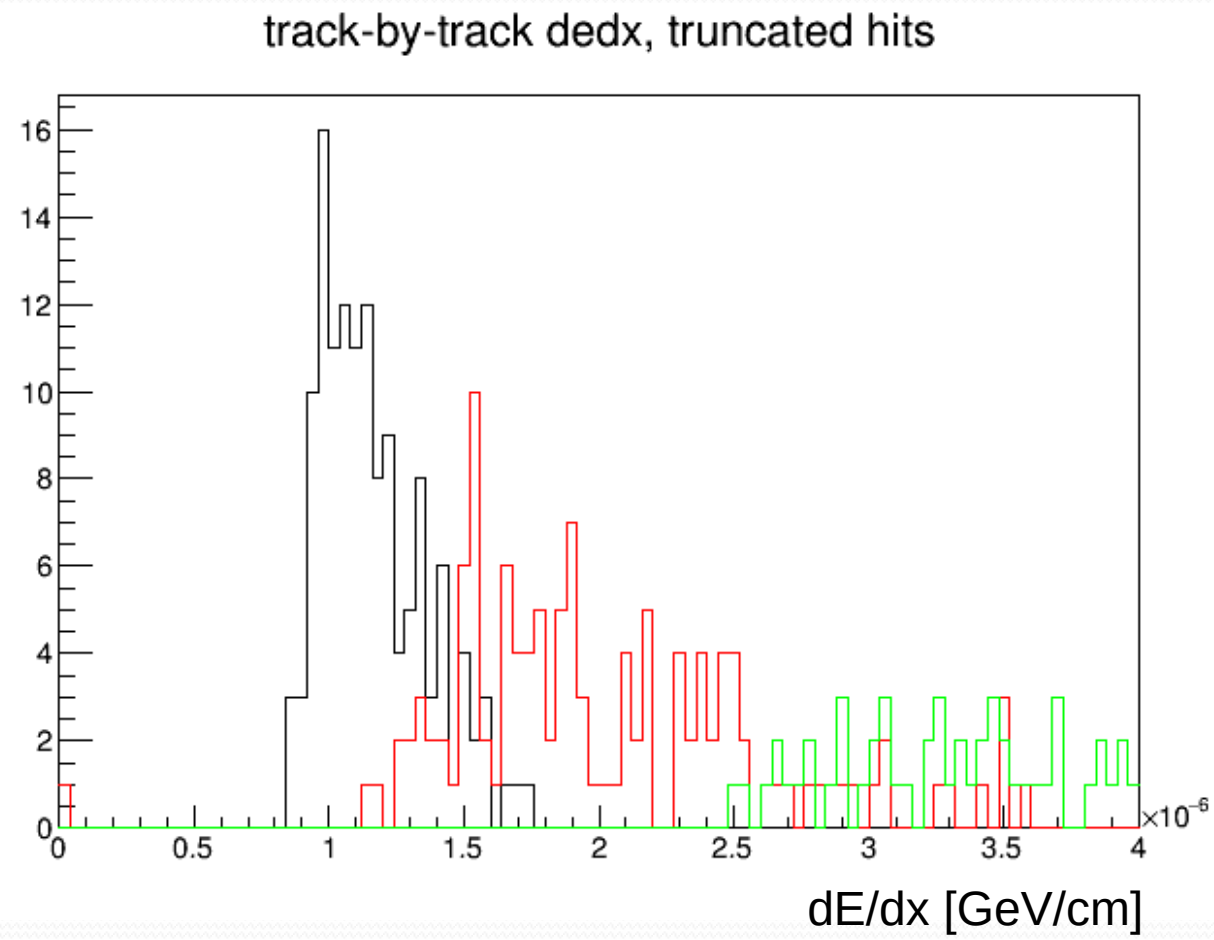


Figure 3: Energy loss in Ar-CH_4 90/10 for different particle species.

Truncated Mean dE/dx, p=300=600 MeV



Black = pions

Red = kaons

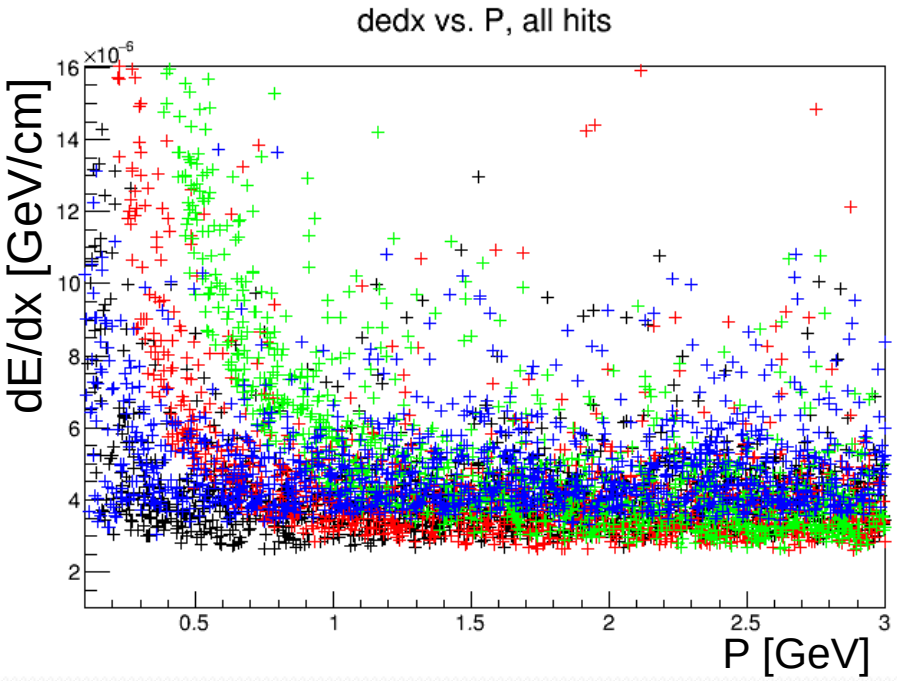
Green = protons

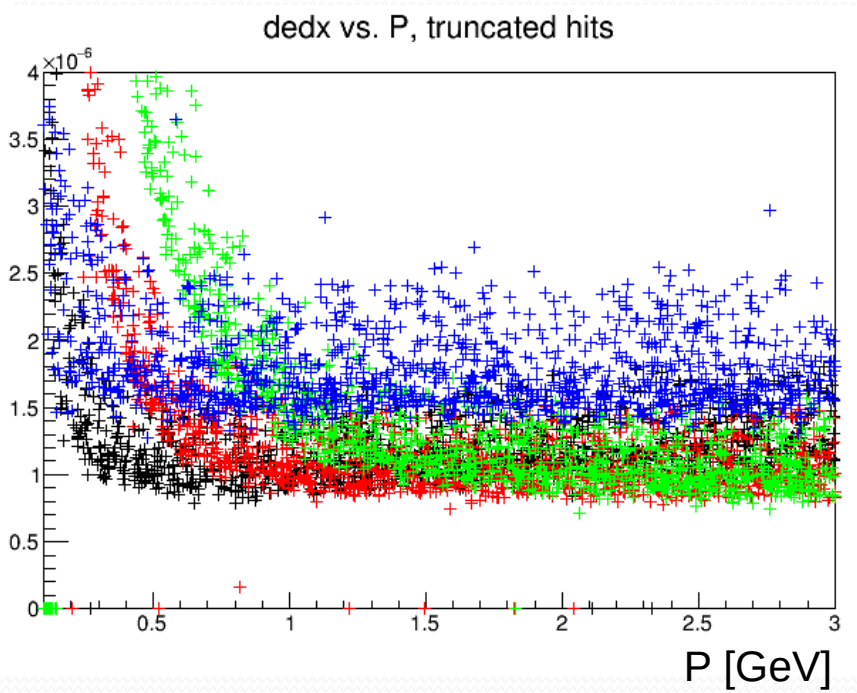
GEANT4 gives good PID separation here.

Getting an integrated dE/dx resolution of 5.6% for pions.

ALICE data yields a 5.7% dE/dx resolution.

Comparison to the Non-Truncated Mean Case





The left plot is made without applying a truncated mean. The right plot is with the application of a 40% truncated mean. Truncating the mean results in cleaner separation between the particle types.

Summary

This was an excellent exercise to get me more familiar with sPHENIX simulations.

The GEANT4 raw edep distribution looks reasonable and behaves as expected for the particle types tested. The performance is surprisingly good.

The STAR TPC particle ID plots are well reproduced within the sPHENIX simulation framework.

Good particle ID with the sPHENIX TPC option looks promising from this study.

This is ready for more in depth studies:

- More statistics.
- Gas type dependence.
- Optimize the truncated mean percentage
- Start adding reality (real hit reconstruction, real tracking, track merging, etc.)